Fire History of Glacier National Park:

Middle Fork Flathead River Drainage

Coop agreement
Systems for Environmental Management

FINAL REPORT FOR COOPERATIVE AGREEMENTS
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FS Contact: J. K. Brown
Co-op Contact: 032, Steve Barrett
034, Larry Bradshaw

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Final Report

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Stephen W. Barrett

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Introduction

In 1984 Glacier National Park (GNP), in cooperation with the USDA Forest Service Intermountain Experiment Station and Systems for Environmental Management, initiated a fire history study in the Middle Fork of the Flathead River drainage. This study was part of a several year effort to document the natural role of fire in GNP ecosystems. Previous fire studies (Barrett 1983, Key 1983) have described fire's historic role in the North Fork of the Flathead River drainage. Park managers recognized that there was a lack of information for the Middle Fork area, and thus sought to further develop their resource data base.

Fire history data are important in the development of fire management plans. For example, knowledge of fire frequencies and severities contribute to managers' efforts to delimit "natural fire zones" within the park. Natural fire zones are areas where fire can be allowed to burn under prescription, thereby assuming a more natural role. Likewise, by identifying forests where fires historically were severe, these data can help managers decide where all fires should be suppressed, or where fire can burn only under very restricted prescriptions.

This report presents the results of a two-phase effort to document the Middle Fork fire history. The goal of Phase I (Cooperative Agreement 22-C-4-INT-32) was to document and map the area's stand age class mosaic. Phase II (Cooperative Agreement 22-C-5-INT 034) sought to interpret the area's fire history.

Study Area

The study area is the Middle Fork of the Flathead River drainage within GNP, about 207,000 acres (83,773 ha.)(fig. 1). The Middle Fork lies in a long, generally steep and narrow canyon, with GNP occupying lands north of the river, and the Flathead National Forest and private lands south of the river. Topographically, the study area is bounded on the west and northwest by the Belton Hills and Snyder Ridge; on the north and northeast by the Continental Divide; on the south and southeast by the Middle Fork of the Flathead River and Bear Creek. Lands immediately south and southeast of the river, primarily on the Flathead National Forest, also were included in the sampling. These lands were included as part of the investigation into whether past fires have frequently crossed the river.

Area elevations range from 3200 feet (975 m.) near West Glacier, to more than 10,000 feet (3048 m.) at the crest of the Continental Divide. The study area, however, generally does not exceed 5500 feet (1676 m.); research was concentrated on the lower-elevation areas because managers are primarily concerned with the fire-initiated forests near agency boundaries and private lands.

The study area is densely forested, with fire-initiated, even-age stands of lodgepole pine (*Pinus contorta*) and western larch (*Larix occidentalis*) dominating most of the area. (Larch and lodgepole pine in western Montana are very intolerant of shade and establishment of an age class requires major disturbance, generally by fire). Subalpine fir (*Abies lasiocarpa*) and Englemann spruce (*Picea englemannii*) are the potential climax trees throughout most of the area, but these species have not acheived widespread dominance or co-dominance in stands because of recurrent fires. Habitat types (Pfister et al. 1977) range from cool-moist to cool-dry, and understory unions in the

Fig. 1. Study area map.

lower elevations of the Middle Fork usually key to moist clintonia (<u>Clintonia uniflora</u>) or drier beargrass (<u>Xerophyllum tenax</u>) with associated phases.

<u>Objectives</u>

<u>Phase I</u>. The general objective of Phase I was to determine the age and distribution of fire-initiated, even-aged stands of lodgepole pine and western larch in the Middle Fork. Of particular interest were the lower-elevation forests on both sides of the river, which is the boundary between GNP and non-park lands to the south. Specific objectives were as follows:

1. Using aerial photography and ground checking by increment coring, document stand age class distributions and initiation dates in the lower-elevation forests of GNP within several miles of the Middle Fork.

2. Determine if the same age classes exist across the river from GNP, on the Flathead National Forest.

3. Prepare a stand age class map for the Middle Fork study area, including the non-park lands adjacent to the river.

<u>Phase II</u>. The general objective of Phase II was to interpret the fire history of the Middle Fork by collecting information on the frequency and severities of historic fires. Specific objectives were as follows:

1. Determine intervals between fires and interpret fire severities in the zone within several miles of the river, using non-destructive sampling techniques. Base the fire history analysis on fire scars and

dates of establishment for age classes of lodgepole pine and western larch.

2. Determine how often past fires crossed agency boundaries and natural barriers. Give special emphasis to fires which crossed the river from inside to outside of GNP. Investigate fire history in the vicinity of major passes and divides bordering the study area to determine if these areas have been effective barriers to fires spreading from the Middle Fork drainage.

Methods

Phase I: Documentation of Stand Age Classes.

1. Site Selections. Three sets of black and white aerial photographs, taken in 1945, 1968, and 1984, were used in selecting increment coring sites in the study area (nominal scales of photographs: 1:12,500; 15,840; 15,840, respectively). The goal was to sample near the margins of adjoining age classes to enable documentation of as many even-aged stands as possible. Stands of differing age structure were identified through stereo photointerpretation, using crown texture, tone, height, and diameter as indices of the relative ages of adjacent classes. The most-strategic sites for stand age analysis were then chosen and marked on 7.5 minute U.S. Geological Survey topographic maps.

2. Field Sampling. After the preliminary delimitation of different-aged stands, the sample sites were visited and evaluated for sampling by verifying the existence of fire-initiated age classes. At

each acceptable site, 3 or more trees from each apparent age class were increment bored at the 1-foot (.3 m.) level.

3. Laboratory Procedures. The increment cores were mounted into core boards and sanded. The cores were then dated by counting annual growth rings under magnification with a 7-25X binocular microscope. For cores that did not contain the pith, estimates were made of the number of years to the pith using the methods described by Arno and Sneck (1977).

4. Data Analysis. The dates of tree establishment (from increment core analysis) were organized as follows, in order to estimate stand-initiation dates. The first criterion was that similar dates of establishment (maximum age range of 15 years) had to be obtained from 3 or more trees in order to be considered indicative of a fire-initiated age class. The 15-year range for defining an age class was considered acceptable because such time spans were commonly found on cores taken from seral regeneration within known burned areas (1929 and 1910 fires). Variables possibly contributing to such core date variation include: 1) different tree-germination years after the fire, 2) inaccurate tree ring counts in the laboratory (e.g., cores having missing or false rings), and 3) inaccurate estimates for the number of annual rings by which an increment core missed the pith. Finally, the assumption was made that the earliest year among a group of similarly-aged trees was the most acceptable approximation of the stand-initiation year.

5. Age Class Mapping. Once the age class dates were determined, a stand age class map could be developed for the Middle Fork. Three

sources of information were examined to produce the map: the aerial photographs (1945, 1968, 1984), the increment core data, and GNP Fire Atlas maps covering the post-1910 period.

The following method was used to mark the distributions and dates of age classes on 7.5 minute topographic maps (scale 1:24,000). The age class dates and sample locations were first labeled on the maps. Age class margins that were visible near the sample sites were then drawn on the maps, and continued to their furthest extents by following the appropriate flight lines; the age class mosaics were adjusted to the 7.5 minute scale by using topographic reference points (contiguous land features such as ridge systems and dendritic erosion patterns were the most useful control points). When unsampled age classes were encountered, stereo-photointerpretation was used to extrapolate the known dates from nearby, similar-textured tree canopies. When extrapolation was not possible, relative-age labels (e.g., "pre-1800") were assigned to the unknown stands by comparing their canopies with those of adjacent stands whose age was known.

<u>Phase II</u>: Fire History Analysis.

The methods of Arno and Sneck (1977) were used to document the fire history. Sampling transects were run throughout the study area, the goal being to locate fire-scarred trees. Rather than cutting large numbers of partial cross-sections from live trees, the method was to use non-destructive sampling techniques suitable for wilderness and parks. Examples of non-destructive techniques are: 1) wedge-sampling of old fire-scarred stumps in or adjacent to GNP, 2) wedge-sampling of live

trees on lands adjacent to GNP, and 3) increment boring of fire scars on catfaced trees within GNP.

For even-aged stands lacking fire scars, stand age dates were the basis for fire history analysis. The method was to document the dates of regeneration resulting from successive stand-replacing fires on a given site (site size generally is less than 200 acres [81 ha.]). First, stand-initiation dates were estimated for surviving trees of old age classes found within the margins of the current younger class (i.e., first estimate stand-initiation dates for the previous, or "veteran", age classes); second, the stand-initiation date was estimated for the current age class; and, third, the ages of the younger stands were subtracted from those of the veteran stands, thereby deriving an approximate chronology for successive stand-replacing fires. Mean fire interval (MFI) was then estimated by dividing the total number of years in the chronology by the number of fire intervals. When it was not possible to calculate MFIs (i.e., when sites lacked evidence of more than 2 fires), fire frequency was analyzed by: 1) simply examining actual fire intervals (estimated from increment cores of succeeding age classes), and by 2) calculating a mean interval based on a compilation of fire intervals from similar sample sites.

To document fire effects, tree inventory plots ($375 m^2$) were taken at each sample site to document habitat type and to serve as a basis for interpreting tree succession. Percent canopy coverage was estimated for each tree species according to 3 d.b.h. classes (0-4", 4-20",20+"). These data were then graphed to depict the canopy coverage of each tree species by size class.

Results

Phase I: Documentation of Stand Age Classes.

Ninety sample sites were increment bored in the Middle Fork study area, mostly in the lower-elevation forests within several miles of the river. The total number of trees bored was 315, and all sample trees were lodgepole pine and western larch apparently representing post-fire regeneration. It was found that most Middle Fork larch and lodgepole pine stands are composed of only one age class.

The study plan had originally called for a minimum of 3 increment cores from each age class found at a site. Exceptions to this rule were judged to be necessary on several occasions, however, when only 1 or 2 sound veteran larch were available to represent an old age class. Age determinations based on these trees were necessary only when repeated coring failed to produce 3 useable cores, and when it seemed certain that the trees were indeed representative of an even-age age class. Tree diameters in excess of 40 inches [102 cm.] d.b.h. were common and many of the trees had rotten centers.

In terms of tree ages, lodgepole pine age classes were rarely found to exceed 150 years in the study area. The oldest, a 172 year old age class, was found in the upper Park Creek drainage. Most of the old larch age classes were between 200 and 250 years old, and a few were between 300 and 400 years old. The oldest tree was a larch in excess of 700 years old (the pith was not obtained but it preceeded the year 1285).

Much of the study area is composed of relatively young forests resulting from 2 very large fires in the early 1900s. In the central and southeastern portions of the study area, large acreages were

regenerated in the aftermath of the very severe 1910 fires. Estimates based on this study's stand age class map (on file, GNP Research Office) suggest that the 1910 fires resulted in about 54,000 acres (21,854 ha.) of nearly total stand replacement, or about 26% of the study area. Field observations within these areas indicate that only the driest south-facing slopes (supporting scattered Douglas-fir [Pseudotsuga menziesii]) escaped total stand replacement. The Fire Atlas and aerial photographs also confirm that tens of thousands of acres were replaced south of the Middle Fork, on the Flathead National Forest.

In 1929, the Halfmoon Fire burned more than 50,000 acres (20,235 ha.) in the Hungry Horse, Apgar, and lower Middle Fork canyon areas (fig. 2). The fire, which originated about 8 miles (13 k.) southwest of GNP, replaced stands from the river bottom to subalpine ridges, and readily crossed the Middle Fork, spreading into the park. About 16% of the study area was burned by the Halfmoon Fire; the stand age class map suggests that the fire resulted in about 34,000 acres (13,760 ha.) of virtually continuous stand replacement in the Belton Hills and lower- to mid Lincoln Creek and Harrison Creek drainages.

The only other large fires occurring in this century were in the lower Coal Creek drainage, which is in the south-central portion of the study area (fig. 3). The 1958 Coal Creek fire burned about 2900 acres (1174 ha.) before it was suppressed, resulting in nearly total stand replacement on all but the dry south-facing slopes. In 1984, the Crystal Creek Fire replaced about 2728 acres (1104 ha.) in the park's lower Coal and Pinchot Creek drainages after crossing the river from the Flathead National Forest (about 323 acres [131 ha.] were replaced in the lower Crystal Creek drainage, where the fire originated).

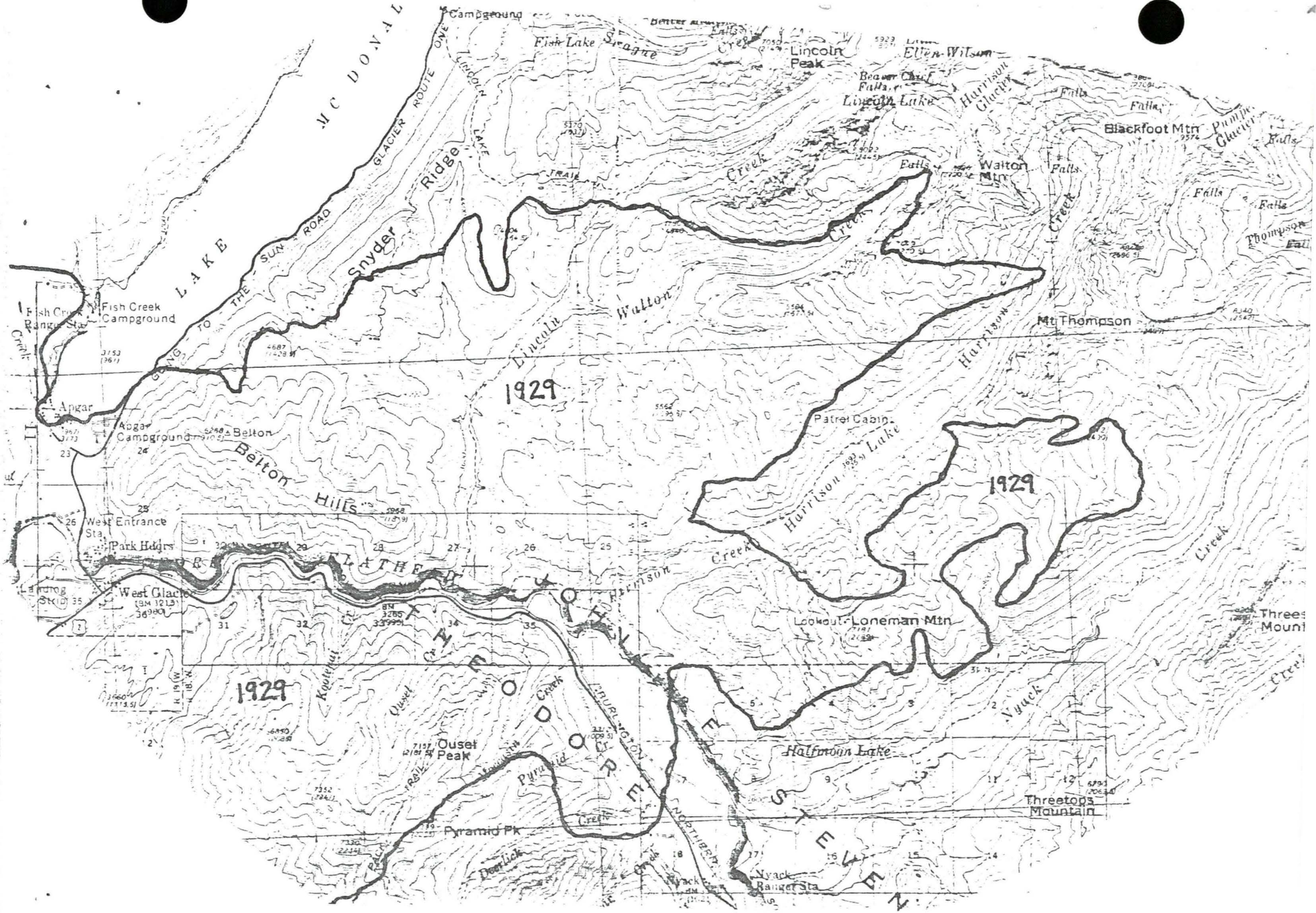
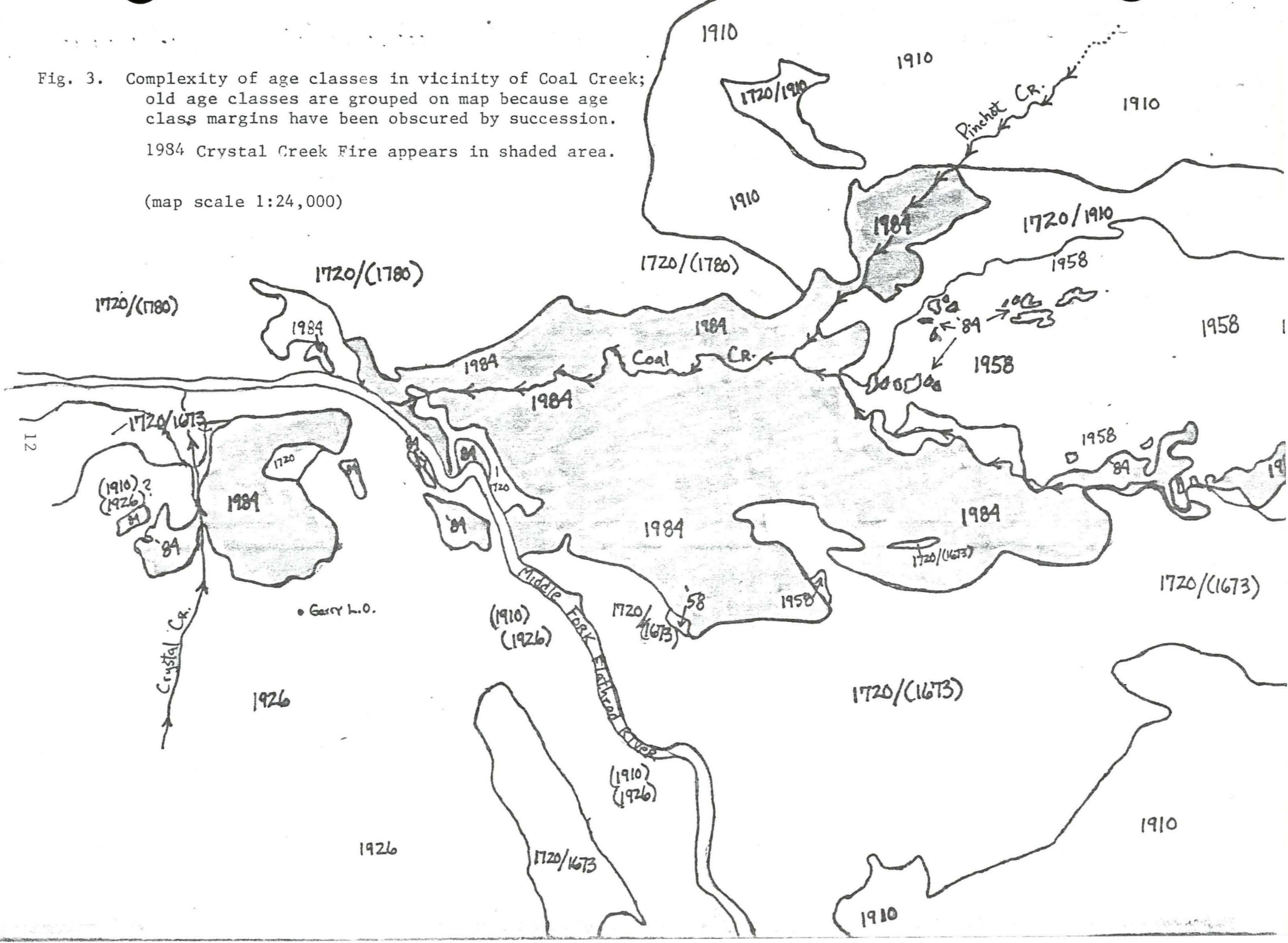


Fig. 2. Approximate margins of 1929 Halfmoon Fire (after: GNP Fire Atlas); area within burn margins is virtually total stand replacement.

Fig. 3. Complexity of age classes in vicinity of Coal Creek; old age classes are grouped on map because age class margins have been obscured by succession.

1984 Crystal Creek Fire appears in shaded area.

(map scale 1:24,000)



The stand age class map also suggests that the Crystal Creek fire reburned about 400 acres (162ha.) that were burned by the 1958 fire.

In summary, nearly 50% of the 207,000 acre study area is composed of even-aged forests of less than 75 years old, a result of 4 stand-replacing fires since 1910. The stands that regenerated after these fires are readily identifiable on the aerial photographs, and most of the stands are relatively large. There are few areas which appear as a "mixed mosaic", that is, areas where the spread of crown fire was patchy or where there was a mix of crown- and surface fire. The Middle Fork's age class pattern differs from that found in the lower elevations of GNP's North Fork valley (Key 1983) and in the nearby Coram Experimental Forest (Sneck 1977), where small stands were common in the age class mosaic.

In the study area's old growth forests, tree ages often were 200 to 250 years, with a smaller component sometimes exceeding 400 years. Aerial photographs were of little value for documenting stand boundaries in the old growth areas because textural differences in tree canopies older than about 150 years were extremely difficult to detect. Transect sampling in the field was more valuable in locating these mixed age classes, but it was not possible to separate old classes in areas that were not visited; old age classes are therefore usually grouped on the stand age class map, with the most numerous seral trees listed first (e.g., "1750/1650")(fig. 3). (Note that a given age class is labeled according to either the actual fire date or the earliest tree establishment date from increment cores, even though seral trees usually regenerate for a number of years after a fire).

The oldest forests are found in the south-central portion of the study area, primarily in the vicinity of Nyack Creek, and Coal Creek. Smaller remnants of old forest also are found in the southwest portion of the study area near Essex, in areas not burned during 1910. Old larch forests also exist in the upper Lincoln and Harrison Creek drainages north of the 1929 burned area. It is noteworthy that multiple-fire-scarred trees are very uncommon throughout the study area, even in these old growth forests.

The increment core dates and locations suggest that a large fire occurred in about 1780 in the western portion of the study area (30 cores were obtained from this class). Remnants of this larch age class can be found in the upper Lincoln and Harrison Creeks, as well as in the lower Nyack Flats area; small groups of surviving trees within this class also were sampled within the margins of the 1929 age class. Substantial portions of the 1780 age class also exist south of the Middle Fork, on the Flathead National Forest. Similarly, relatively widespread evidence of a larch age class dating to about 1720 also was found on both sides of the river, in the area between about Crystal Creek and Tunnel Creek (8 cores). These stands, however, are not as continuous as the 1780 class, and are interspersed with the 1910 age class. The oldest verifiable fire-initiated forests were found in the area between Paola Creek and Essex, where 4 cores were obtained from a larch age class which originated after a fire in about 1673. This age class also is found on both sides of the Middle Fork.

In the upper Park Creek drainage, 2 lodgepole pine age classes apparently originated after fires in about 1813 and 1843 (16 and 6 cores, respectively). These stands exist in both a continuous- and

small mosaic pattern. These relatively decadent stands are now undergoing an epidemic of mountain pine beetles (Dendroctonus brevicomis). Other substantial acreages of 1800s-regenerated lodgepole pine are found in the Marias Pass area, at the study area's southeastern edge. Here, a relatively extensive 1885 age class (18 cores) exists in both a continuous- and small mosaic pattern adjacent to the 1910 age class.

In summary, about 30% of the study area is composed of old growth, fire-initiated forests, most older than 200 years. Many of the old age classes regenerated after large fires which occurred between about 1673 and 1780, and this often produces a gap of from 150-250 years between adjacent old- and young age classes in the area.

Phase II: Fire History Analysis.

An important finding during the field sampling was that multiple-fire-scarred trees were rarely encountered even in the old growth areas. Larch with single fire scars occasionally were found near the margins of large burns but such trees are of little value in documenting long-term fire history; the investigator need only core the adjacent younger age class to obtain a close estimate of the fire year. This method is more economical and less damaging than the technique of trying to obtain the actual fire date by coring the fire scars. The Middle Fork's dearth of multiple-fire-scarred trees thus made it necessary to base the fire history interpretations upon age class analysis.

The data and field observations suggest that Middle Fork stands usually fit a long fire interval/total stand replacement fire history pattern. Analysis of age class chronologies for 10 sites suggests that area stand-replacement intervals generally range from 150-300 years (table 1)(fig. 4). A given site's chronology is constructed from cores from the present age class, as well as from surviving larch found within area snagfields (previous age classes). In 2 cases, the chronology was extended back more than 400 years to document 3 successive age classes. These 2 sites provided the study's only MFI statistics (195 and 177 years). For example, cores from the lower Harrison Creek area suggest an age class chronology of 1539-1780-1929 (approximate stand-replacement intervals: 149 and 241 years). It was not possible to calculate MFIs for the remaining 8 sites because only 1 fire interval (2 fires), or a partial interval (1 fire), was recorded for each site. The single fire intervals of 6 sites were combined, however, to produce an MFI estimate of 228 years for the broad area (site numbers 4, 5, 6, 7, 8, and 10

Table 1. Age class chronologies for 10 sites, Middle Fork of the Flathead River drainage, Glacier National Park.

Site No.*	Hab. Type	Elev. (ft.)	Age Class Chronology Class	Class	Class	Total No. Years	No. Fires	Fire Interval Range	MFI**	General Location
1	Abla/Xete	4800	1575	1780	1929	410	3	149-205	177	Snyder Ridge, Lincoln Tr.
2	Abla/Clun	3600	-	1780	-	205	1	205^{+}	-	Lower Harrison Lk. Trail
3	Abla/Clun	3600	1539	1780	1929	446	3	149-241	195	Harrison Cr. mouth area
4	Abla/Clun	4000	1593	1780	-	392	2	$187-205^{+}$	-	Lower Loneman Trail
5	Abla/Clun	3600	1562	1894	-	423	2	$91^{+}-332$	-	Nyack Quarry area
6	Abla/Clun	4000	1673	-	1926	312	2	$59^{+}-253$	-	Lower Hidden Cr. Trail
7	Abla/Clun	4000	-	1720	1910	265	2	$75^{+}-190$	-	Lower Stanton Cr. Trail
8	Abla/Clun	4000	1673	-	1910	312	2	$75^{+}-237$	-	Essex area
9	Abla/Clun	4000	1673	-	-	312	1	312^{+}	-	Hwy. 2 south of Walton R.S.
10	Abla/Xete	4000	-	1750	1919	235	2	$66^{+}-169$	-	Md. Fork/Bear Cr. Jct.

* Site size generally is less than 200 acres (81 ha.); locations appear in fig. 4.

** MFI calculations based on period between earliest and latest fires.

"+"= fire interval length as of 1985.

Fig. 4. Table 1 sample sites.

[table 1]) (the other 2 sites had only partial fire intervals and were thus not included in the mean calculation).

Fires also occurred in the Middle Fork after relatively short intervals, but apparently only rarely. Near Marias Pass, for example, some of the areas's 1885 age class appears to have been replaced after just 25 years, in 1910, but fire spread was very patchy. The lower Coal Creek drainage provides useful data on short as well as long fire intervals. The drainage has experienced 3 stand-replacing fires in this century, in 1910, 1958, and 1984. The 1910 fire apparently replaced trees of the 1720 age class, or older. This results in a 190-year, or longer, stand-replacement interval, agreeing well with the study's fire frequency estimates. The 1945 photographs, however, indicate that the 1958 fire replaced post-1910 and post-1720 regeneration (stand replacement intervals: 48 and 238 years) before being suppressed at about 2900 acres. The 1984 fire, which was partially suppressed, replaced both 1958 and 1720 regeneration in roughly equal amounts (stand replacement intervals: 26 and 260 years).

In replacing stands that were 26 years old as well as ones in excess of 260 years, the 1984 fire illustrates the possible range of stand-replacement intervals. The 260 year statistic agrees well with the estimates presented above but, overall, the data suggest that stand replacement at less than 50 years probably is an unusual occurrence in the Middle Fork's relatively moist forests. At the other extreme, a small spruce/fir stand was found where there evidently has not been a stand-replacing fire in more than 700 years. This stand, which is outside the main study area, is on a low-elevation slope above Rescue Creek (Flathead National Forest) and it produced the study's oldest larch, which pre-dates the year 1285; the tree is one of the last few representatives of any seral species in this otherwise climax stand. This

extremely long fire interval probably is due to chance because the habitat type is similar to others in the vicinity which have burned within the last 2 centuries, and there do not appear to be any major topographic barriers to fire nearby.

Results suggest that fire suppression has not yet measurably affected Middle Fork stands. Examination of the data's longest fire intervals (table 1), all of which occurred before the era of efficient fire suppression, suggests that today's old growth stands are within the range of natural fire intervals (examples of maximum fire intervals found: 241, 253, 332 years; examples of today's maximum stand ages: 205, 265, 312 years). The few potentially large fires which have been suppressed, such as in 1958 and 1984, might have replaced some of the 200 year old larch stands in the study area's south-central portion. Still, the current fire intervals in these stands have not exceeded the longest intervals documented for the pre-suppression era. Elsewhere in the study area, the oldest stands clearly are approaching the upper end of the historic range of fire intervals. For example, the age class map suggests that stand succession is most developed in the mid- to upper Lincoln and Harrison Creek drainages, and lower Nyack Creek areas (just southeast of Nyack Flats, old forests exist on both sides of the river, perhaps suggesting a potential high-risk area in terms of fires crossing agency boundaries).

The fire history results for this study differ substantially from those for GNP's North Fork of the Flathead River drainage. Multiple-fire-scarred trees were numerous and widespread in the North Fork's lower elevations (Barrett 1983), and fire scars were rare in the steeper, upper elevations; in the gentle lowlands below about 5000 feet (1524 m.) lodgepole pines frequently had 1 or 2 fire scars each and larch and ponderosa pine often had from 3 to 6 scars each. North Fork fire intervals generally ranged from 15-70 years in the lower elevations (the average of MFIs from 20 sample stands was 38 years)(no data were obtained for upper-elevation stands). In the Middle Fork study area, most of which also is below 5000 feet, no fire scars were found on lodgepole pines, larch only rarely had one scar, and fire intervals ranged from 150 to 300 years (average of the data's 2 MFIs: 186 years).

The effects of past fires also were different in the 2 study areas. The fire scars on North Fork trees were produced by surface fires, and these sometimes occurred in conjunction with the area's large stand-replacing fires. In his study of the North Fork area, Key (1983) found a mix of well-defined and unclear age class margins on aerial photographs, a result of this interaction between crown- and surface fire. Small mosaics also were common age class patterns in the lower elevations of the North Fork, again a result of the interaction between crown- and surface fire. By contrast, aerial photographs for the Middle Fork reveal that fires usually made large stand-replacing runs, often from the river bottom to subalpine ridgetops; the resulting age classes appear more extensive, and the burn margins generally are well-defined (the exception is in areas where many years of stand succession have obscured the burn margins on the aerial photographs). Evidence of large stand-replacing runs also was found in the North Fork (Key 1983), but generally only in the steep upper elevations.

Differences in climate and topography appear to be major factors contributing to the different fire histories. In the North Fork, mean annual precipitation at Polebridge Ranger Station (elevation: 3550 feet [1082 m.]) is about 23 inches (58 cm.)(Finklin 1985). Mean annual precipitation for the Middle Fork's Walton Ranger Station (elevation: 3760 ft. [1146 m.]) is about 40 inches (102 cm.). The Middle Fork's more-moist environment undoubtedly reduces the chance for many ignitions to develop into spreading fires as often as might occur in the North Fork, thus allowing longer periods for fuel accumulation. Additionally, the topography throughout most of the Middle Fork is uniformly steep, apparently enhancing the development of running crown fires. Conversely, the lower elevations of the North Fork are composed of gently sloped moraines which end abrubtly at the base of the steep Livingston Range. North Fork aerial photographs verify that large crown fires occurred most often in the steeper topography.

One goal of the study was to investigate whether past fires have historically crossed the Middle Fork river. Park managers' concern was whether modern fires originating in GNP are likely to spread to lands outside the park. Results suggest that the Middle Fork was crossed by every large fire in the past 265 years; many increment cores were obtained from age classes which originated after large fires in 1720, 1780, 1910, and 1929 (a fire apparently also crossed the river near Essex in about 1673, but 300+ years have obscured the evidence and it is not known if this was a major fire). Similarly-aged classes exist on both sides of the river throughout the 30 mile (48 k.) length of the Middle Fork canyon. These stands are usually found right up to the river's edge, so the assumption is that the fires actually did cross the Middle Fork, as opposed to just burning north and south

of the river at different times during a fire season. This phenomenon was well illustrated by the 1984 Crystal Creek Fire (fig. 3). A lightning fire in the lower drainage rapidly spread downslope through the tree canopy, jumped the Middle Fork, and continued through the canopies of GNP's lower Coal and Pinchot Creek stands.

In terms of directions of fire spread, apparently no fires have escaped from GNP by jumping the Middle Fork during the period of written records. However, several fires have crossed the Middle Fork and entered GNP over the past 75 years (in 1910, 1929, and 1984). For example, in addition to the recent Crystal Creek Fire, the Fire Atlas shows that the very large 1929 fire started outside the park, near the town of Hungry Horse, crossed several major divides, and covered more than 20 airline miles from the point of origin to its furthest eastern extent. The severe 1910 fires burned even greater expanses on both sides of the Middle Fork, although the points of origin are less clear (area ignitions were numerous and written records are sketchy, but it is generally accepted that the fires entered GNP from the Flathead National Forest).

There is no reliable way to document directions of fire spread before the period of written records. Extrapolation of modern weather patterns probably is the best indicator. Summer weather fronts typically cross over the area from southwest to northeast, so most lightning storms in the past undoubtedly encountered the high Flathead Range before crossing the Middle Fork and passing over park forests. Early-day large fires thus presumably often originated south of the Middle Fork, just as fires have in modern times.

Fire History near Mountain Passes and Divides

One objective of the study was to document the ages of fire-initiated forests on both sides of major mountain passes and divides which border the study area. Park managers wanted to know if these areas have been effective barriers to the spread of past fires; knowledge of historic fire patterns might help park personnel define fire policies and develop fire prescriptions for such areas.

The sampling method was to determine the ages of fire-initiated stands on both sides of selected passes and divides. The extent of each stand would then be traced using aerial photographs; only the most-recent stand-replacing fires could be documented because of the dearth of fire-scarred trees.

Four areas were chosen for investigation, 3 of them straddling the Continental Divide. Two passes, Firebrand Pass and Two Medicine Pass, are in steep, rocky alpine areas with elevations of about 7000 feet (2134 m.). Lodgepole pine forests typically extend up to about 6000 feet (1829 m.) before drastically thinning into krummholz and alpine environments. The other 2 sample sites, Marias Pass and Snyder Ridge, are densely forested and relatively low-elevation areas (about 5200 and 4400 feet [1585 and 1341 m.], respectively).

Firebrand Pass. Firebrand Pass was found to have been crossed by the area's last large fire, which occurred in 1910 (fig. 5). On the pass' southwest side, this fire swept virtually the entire Ole Creek drainage, approximately 16 miles (26 k.) in length. Increment cores and aerial photographs revealed that there are few trees older than 75 years in the drainage today. On the northeast side, the Railroad Creek drainage also is composed mostly of the 1910 age class. Charcoal and snags were observed all the way to the top of the pass, indicating that the 1910 fire had actually

Fig. 5. Age classes in vicinity of Firebrand Pass; 1910 class occupies virtually entire area.

burned through about 2 miles (3.2 k.) of widely scattered krummholz and treeless environment.

Two Medicine Pass. The Continental Divide in this area has been an effective barrier to fires for at least the past 170 years (fig. 6). The lodgepole pine forests in the upper Park Creek drainage, southwest of the pass, dated to about 1813. Two age classes (1761, 1875) exist on the northeast side of the pass, in the Cobalt- and Paradise drainages. The linear distance separating the eastside- and westside forests is less than that in the Firebrand area, but Two Medicine Pass is on top of a steep-sided ridge which separates 2 deep glacial cirques. The pass is about 1500 feet (457 m.) above the continuous forests and fuels above the forested zone are limited to tiny, widely scattered cushion plants inhabiting scree; large windborne embers would thus be necessary for fires to breach this formidable alpine barrier. (By contrast, the ascent to Firebrand Pass is more gradual, and the scattered krummholz islands evidently provided enough fuel for the 1910 fire to "leapfrog" over the Divide).

Of potential interest to fire planners, the upper Park Creek stands are now decadent and undergoing a mountain pine beetle outbreak, suggesting that these stands might support a hot fire if ignited under favorable burning conditions (these 172 year old pines were by far the oldest documented in the study).

Marias Pass. Marias Pass is a very broad, forested saddle on the Continental Divide, and only attains an elevation of 5200 feet (1585 m.)(fig. 7). The gentle topography is covered by a dense, somewhat stunted forest of lodgepole pine, and there is abundant evidence of spreading fires. Both of the most-recent fires, 1910 and 1885, are well represented in the area's age class mosaic. The patchy nature of the mosaic, however, suggests that the

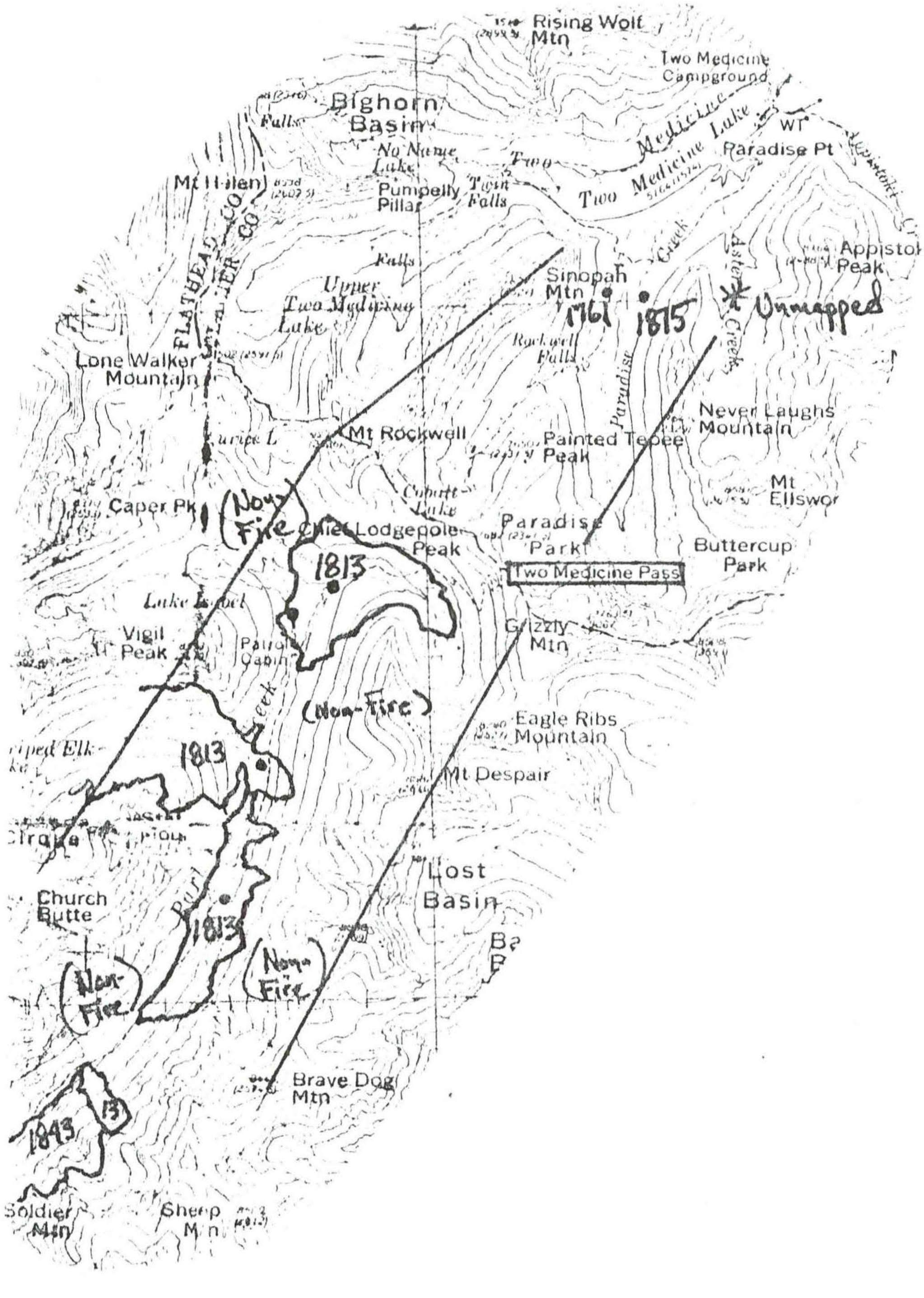


Fig. 6. Age classes in vicinity of Two Medicine Pass; alpine pass separates lodgepole pine classes which regenerated after fires in about 1813 and 1761/1875.

Fig. 7. Mosaic of 1910/1885 age classes on both sides of Marias Pass; similar tree ages make it difficult to separate classes.

1910 fire had spread relatively slowly over the pass itself. The 1885 age class is much more continuous than the 1910 class, suggesting that a relatively large fire had occurred 25 years earlier. In addition to being occupied by dense lodgepole pine stands, Marias Pass is frequently subjected to high winds, a fact which is potentially important to fire planners because the park's southern boundary is on the pass.

Snyder Ridge. Snyder Ridge (elevation: 4400 feet [1314 m.]) is a relatively gently sloped ridge separating the McDonald Creek and Lincoln Creek drainages (fig. 8). Park managers were interested in this area's fire history because the ridge borders the Lake McDonald basin, which contains private inholdings, administrative facilities, and is heavily travelled by tourists in the summer. Increment cores from the old growth larch/redcedar (*Thuja plicata*) forests on the Lake McDonald side of Snyder Ridge dated to about 1740. Just east of the ridge crest, on the Lincoln Creek side, larch and lodgepole pine dated to about 1780. Aerial photographs do not shed light on the possible interspersion of the 2 similarly-aged classes because it is virtually impossible to detect differences in the area's tree canopy.

Large fires probably would have little difficulty crossing this heavily forested divide. Also, the larch forests along Snyder Ridge were among the oldest documented in the study; the more than 200 years of stand succession suggests that the area's fuels have accumulated to the point where a large fire might be supported under the right burning conditions (historic fire intervals in the area usually ranged from 150-300 years).

In summary, only 1 of the 4 sampled areas was found to be an effective barrier to fires within the last 200 years. The cliffy alpine areas of the Continental Divide undoubtedly represent the best fire barriers. Map inspection of the area's other 5, unsampled, passes along the Continental

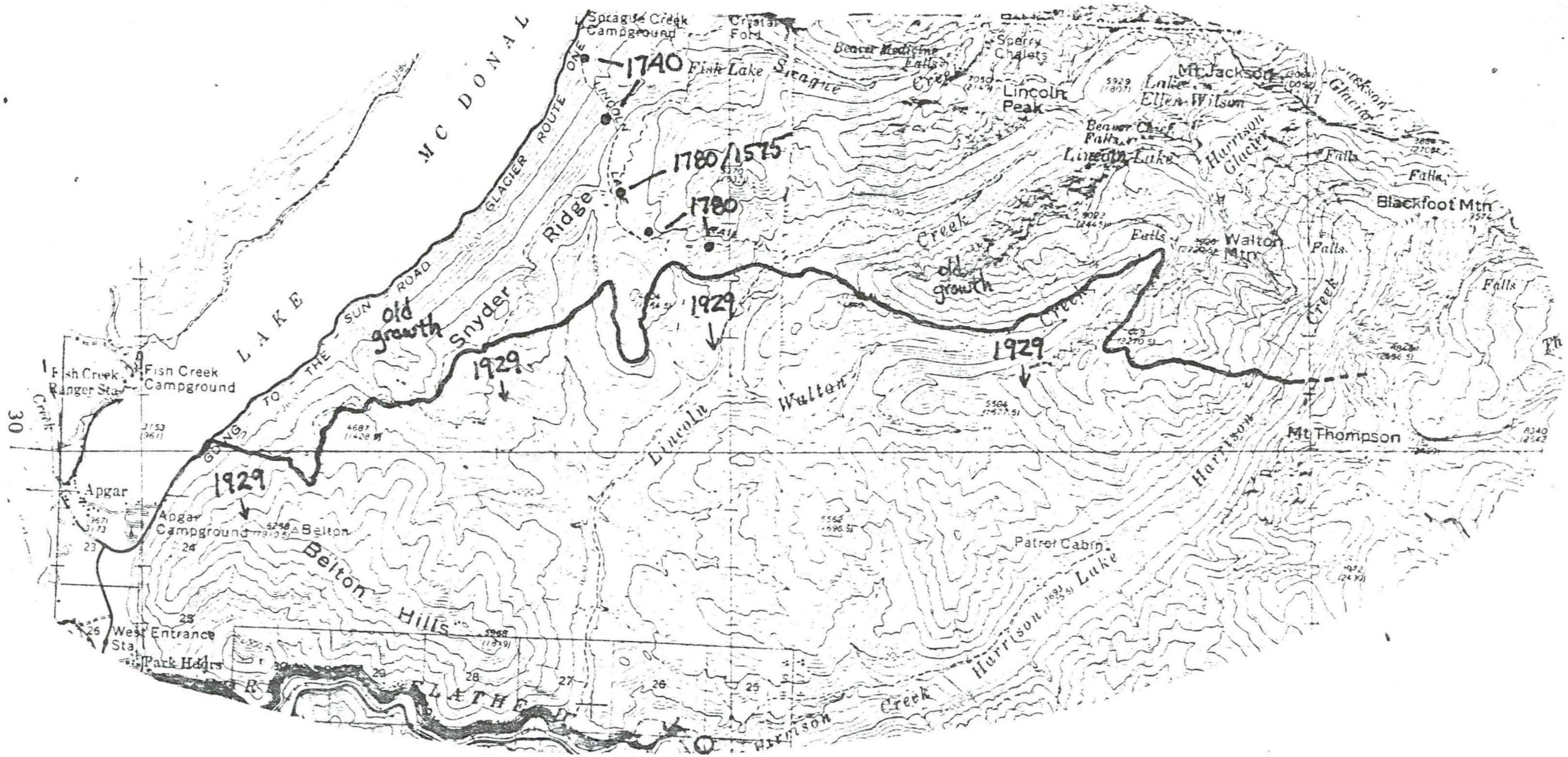


Fig. 8. Age classes in vicinity of Snyder Ridge; similar old tree ages make it impossible to separate classes on aerial photographs.

Divide reveals that 4 of 5 passes are rocky, alpine environments similar to Two Medicine Pass (i.e., Dawson, Cut Bank, Triple Divide, and Gunsight passes). Red Eagle Pass is a relatively broad saddle occupied by continuous vegetation, but the basins on either side of the pass are very moist and composed mostly of uneven-aged stands and avalanche communities. Evidently few Middle Fork fires would have the potential to burn up to and cross most areas of the Continental Divide (fire-initiated stands usually are very patchy, or non-existant, at the heads of the creek drainages). Further, these areas are located well within park boundaries, away from major facilities. Conversely, the lower-elevation areas near Snyder Ridge and Marias Pass are heavily forested with fire-initiated stands, and also are near park facilities, private in-holdings, and agency boundaries.

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